RETROSPECTIVE ASSESSMENT OF CARIES EXPERIENCE AMONG U.S. NAVAL ACADEMY MIDSHIPMEN

by

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MASTER'S THESIS

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ABSTRACT

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AMONG U.S. NAVAL ACADEMY MIDSHIPMEN

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Objective: To assess the 4-year caries incidence (from matriculation to graduation) among U.S. Naval Academy Midshipman.

Methods: Dental records (n = 300) from a total population of 1006 midshipmen from the 2011 graduating class at U.S. Naval Academy, Annapolis, MD were randomly selected for review. Patients were assigned a caries risk status based on the number of caries lesions recorded at the initial examination (Low = 0 lesions; Moderate = 1-2 lesions; High = 3+ lesions). For each risk category, caries prevalence (DMFS, DMFT, incipient surfaces) and caries incidence were calculated based on findings recorded at the initial (E1), third-year (E2), and fourth-year (E3) examinations. The most significant predictors for caries incidence were determined for each risk category by linear regression analysis.

Results: The gender distribution included 239 males (79.7%) and 61 females (20.3%); median age was 18 years (range = 17–22). Mean DMFS and DMFT were significantly different for each risk group at each examination (Low < Moderate < High; one-way

ANOVA, $p < 0.05$). Within each caries risk category, mean DMFS and DMFT increased significantly from E1 to E3 (repeated measures ANOVA, all $p < 0.05$). Compared to low-risk patients, total caries incidence was 2.3X greater for moderate-risk and 3.7X greater for high-risk patients (one-way ANOVA, $p < 0.05$). The most significant predictors for caries incidence among all risk groups (Low-, Moderate-, and High-Caries risk combined) were decayed surfaces and decayed surfaces plus incipient surfaces (Linear Regression; all $p < 0.01$).

Conclusions: Caries experience was consistently greater for moderate- and high-risk patients at all examinations. The magnitude of increase in caries experience was greater for moderate- and high-risk patients. Caries history and current disease status reliably predict future caries experience in this young adult population.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

1.	DMFS	The number of decayed, missing, and filled surfaces (adult)
2.	DMFT	The number of decayed, missing, and filled teeth (adult)
3.	NHANES	National Health and Nutrition Examination Survey
4.	TSCOHS	Tri-Service Center for Oral Health Studies
5.	ODRM	Oral Disease Risk Management
6.	PSR	Periodontal Screening and Recording

CHAPTER I: REVIEW OF THE LITERATURE

Dental caries is a multifactorial, chronic disease that reaches across all age groups and populations throughout the world. Epidemiological studies from the past several decades demonstrate consistent patterns of incidence, lesion progression, and specific risk indicators associated with dental caries. Available data to assess trends in caries are abundant, with studies such as the National Health and Nutrition Examination Surveys (NHANES) I – III sampling large populations, while smaller studies have examined specific groups based on age or among military personnel.[1-4] Whether data are gathered from large or small sample sizes, certain general trends are evident. Caries prevalence has declined among all age groups in the U.S. since the 1970s;[5-7] the incidence of new caries lesions tends to decline as one ages from adolescence to young adulthood,[8,9] but increases again through adulthood; the rate of lesion progression through enamel is slower than in dentin;[10,11] and past caries experience is the strongest predictor of future caries development.[12-15]

Current understanding of dental caries indicates that the disease is of microbial etiology, is dietary-dependent, and is a host-modified process exhibiting periods of quiescence and exacerbation.[16] The development of a caries lesion requires the presence of acidogenic bacteria, including mutans streptococci or lactobacilli, and fermentable carbohydrates (e.g. glucose, sucrose, fructose, or cooked starch) to produce an acidic waste product (lactic acid) subsequent to bacterial metabolism.[17] Demineralization of enamel and dentin result from acid dissolution of calcium phosphate that comprises natural tooth structure. Treatment of dental caries requires placement of a restoration, or remineralization therapy if the lesion has not caused cavitation of the enamel.

Dental Caries Prevalence and Incidence

Epidemiological studies have provided an understanding of disease prevalence and incidence within specific and general populations. Prevalence is defined as "the fraction (proportion) of a group possessing a clinical condition (e.g., caries) at a given point in time."[18] Incidence is "the fraction (proportion) of a group initially free of the condition that develops it over a given period of time."[18] For dental caries, incidence is most often expressed as the number of new caries lesions per person over a selected period of time (e.g., one to three years).

In the United States, the NHANES I report[19] provided data for a sample of approximately 28,000 people from 1971 to 1974. The survey recorded decayed, missing, or filled surfaces (DMFS) and mean number of decayed surfaces among different age groups, genders, races, income levels, and education levels. The study was repeated from 1986 to 1987 with the second NHANES survey[20,21] of 27,801 people, and conducted again from 1988 to 1994 with a sample of 39,695 people in the NHANES III survey.[22,23] As compared to NHANES I, NHANES III revealed significant reductions in mean DMFS (27%) and decayed ('D') surfaces (50%) among adults between 18 and 45 years of age (DMFS: 38.30 to 27.86; D: 3.64 to 1.82).[6] The reductions were most profound among 18-25 year-olds (DMFS: 24.78 to 13.85 = 44%; D: 3.89 to 1.84 = 53%), with lesser reductions evident as age increased from 26-35 years (DMFS: 42.07 to 25.68 = 39%; D: 3.83 to 1.99 = 49%) to 36-45 years (DMFS: 52.23 to 41.02 = 21%; D: 3.05 to

1.61 = 47%). NHANES III also revealed a significant decrease in the number of adults aged 18 to 45 years with untreated caries (from 50.7 to 29.0 percent).

Similarly, among children age 6 to 18 years, the number of decayed, missing, or filled permanent teeth (DMFT) decreased by 57.2 percent (DMFT: 4.44 to 1.90); and among children age 2 to 10 years, the number of decayed or filled primary teeth (dft) decreased by 39.7 percent (dft: 2.29 to 1.38) from NHANES I to NHANES III.[24] Statistics from the *Health, United States, 2009* report from the National Center for Health Statistics (NCHS) and Centers for Disease Control and Prevention (CDC) indicated that the prevalence of untreated caries among 6-19 year olds has declined by 38.6% over the past three decades.[25] While the data indicate a reduction in overall caries experience in the primary and permanent dentitions among U.S. children from 1971 through 2004, untreated caries remain in 19.5% of children age 2-5 years and 22.9% of children age 6-19 years.

Rate of Dental Caries Progression

Current literature indicates that caries lesions progress quite slowly through enamel, but more quickly as they advance through dentin.[8,10,11,26-28] A study of caries progression among school children in western Australia indicated that the median time for lesions in enamel to advance into dentin was over six years, with at least 60 percent remaining in enamel for approximately 3 years.[29] This is consistent with a review by Pitts indicating 5-6 years for lesions in outer enamel to progress into dentin.[11]

In a longitudinal assessment of caries incidence and progression in a cohort of 536 Swedish children from ages 11 to 22 years, Stenlund and colleagues[9] reported that the median time from baseline to the appearance of the first new approximal caries lesion was 2.0 years (first quartile = 0.7 years; third quartile = 4.7 years). Seventy-five percent of sound enamel surfaces (no visible radiolucency) survived from 3.0 to 9.0 years (median = 6.3 years) without showing evidence of caries progression to the dento-enamel junction (DEJ).[10] Caries lesions radiographically limited to enamel survived 3.4 to 6.6 years (median = 4.8 years) before advancing to the outer half of dentin; and lesions already at the DEJ required 2.0 to 6.8 years (median = 3.1 years) to reach the outer half of dentin. Evaluating the same cohort again at age 26-27 years, Mejare and colleagues[8] reported fewer new enamel lesions (on both approximal and occlusal surfaces) and a slower rate of caries progression than in earlier years. Over half (56%) of all approximal surfaces remained sound, and only 11% had been restored or had lesions in the outer dentin. Moreover, 46% of the approximal enamel lesions had not progressed into the outer half of the dentin.

Disparities in Caries Experience

Recent NHANES data (1999 – 2004) indicate that caries experience among adults and older children has continued to decline, although at a slower pace than previously observed; however, the prevalence and severity of dental caries among younger children have not declined further, and, may have increased among those of certain racial/ethnic groups and lower income levels.[30-33] These disparities suggest a skewed distribution, rather than a universal reduction, in caries experience. For example, although a majority of children in the U.S. reach adulthood with relatively little caries experience, fewer than 30% of 18-year-olds and 10% of all adults (age 20+) are completely caries-free.[30] Moreover, approximately 20% of U.S. children suffer from severe caries (DMFS ≥ 7); and 70% of the total caries experience among U.S. children occurs in less than 30% of the population.[19, 20, 22, 23] Comparing data from NHANES III (1988-1994) to NHANES 1999-2004, Dye and colleagues noted significant increases in overall caries experience among 2- to 4-year-olds (from 19% to 24%),[32] poor non-Hispanic white children aged 6-8 years (8% to 22%), and poor Mexican-Americans aged 9-11 years (38% to 55%).[31] Thus, although overall caries experience among children and adolescents continues to decline, certain subgroups within the population exhibit trends of increasing caries prevalence.

Caries Prediction and Risk Assessment

Past caries history is the strongest, most consistent single predictor for future caries experience.[12,13,34] Many studies have shown positive associations between past and future caries experience.[14,15,34,35] A study of 631 U.S. Naval service members indicated that 92 percent of patients with deep caries lesions at their baseline examinations presented with one or more new caries lesions at their first subsequent annual recall examinations.[2] Conversely, 66 percent of patients who presented with no caries at the baseline examination were still caries-free at the recall appointment.

In their long-term study of Swedish children from ages 11 to 22 years, Stenlund and colleagues[9] reported that, of the subjects who developed new approximal caries, 36 percent developed new lesions within the first year; by the third year, 70 percent had developed new lesions; and by age 17 (fourth year following baseline), 82% had developed new lesions. The presence of two approximal lesions at baseline (age 11-13) doubled the patient's relative risk of developing additional lesions, and the relative risk of developing new approximal lesions increased as the number of lesions at baseline increased. Regardless of baseline caries experience, by age 22, 85% of all patients had developed at least one new approximal lesion. Even among patients who had no approximal lesions at baseline, the likelihood of developing approximal lesions by age 22 was 80%.

Bartoloni and colleagues assessed longitudinal changes in caries risk among over 273,000 U.S. Air Force personnel from 2001 to 2004.[1] Results indicated that the proportion of personnel at high risk for developing caries lesions declined from 11.0 to 7.6 percent; the proportion at moderate risk declined from 19.7 to 17.3 percent; and the proportion at low risk increased from 69.2 to 75.1 percent. In addition, the study reported that 84.4 percent of personnel who were considered low caries risk at the beginning of the study remained at low risk at the conclusion of the study. These data suggest that caries experience can remain consistently low as one gets older, and individuals can maintain low caries risk well into adulthood, especially for a well-monitored population with adequate access to preventive care. However, the study also noted that, despite an overall reduction in high caries risk among active duty Air Force members, those of younger age, less education, lower rank, and fewer years in service, as well as users of tobacco, made up the majority of those identified as high caries risk.

Epidemiological studies have shown less caries reduction among smokers,[37] individuals with less education,[4] and individuals in the United States below the federal poverty line.[5] Studying a random sample of young adults in South Australia, Roberts-Thomson and Stewart noted a higher mean number of decayed surfaces among the unemployed, individuals who received dental care at public clinics, and those receiving government benefits.[37] Thus, while overall caries prevalence has declined, certain risk indicators (e.g., smoking, low income, and lack of education) can be utilized to identify specific groups who remain at elevated risk for dental caries.

Data from the NHANES III survey support the view that lower caries rates may extend to aging populations if caries prevention efforts are maintained through childhood – a suggestion initially presented by Carlos and Wolfe in 1988.[5,38] Based on existing literature, it is, therefore, reasonable to expect that, barring significant changes in health, dental maintenance, access to care, or personal lifestyle, children, adolescents, and young adults with low caries experience should remain so through adulthood.

Caries Experience in the U.S. Military

Oral health is a significant component of general medical health. The U.S. military services place a high priority on maintaining optimum health among their members. Dental readiness of military personnel directly effects deployment status, thus greatly influencing the primary objective of a military with global reach. Furthermore, the development of oral disease during deployment compromises mission readiness and may require a significant financial rectification. Studies of recruits have been performed to assess the prevalence of caries among personnel entering service in both U.S. and foreign militaries.

The literature indicates a decline in caries prevalence over the past two decades among non-U.S. military personnel. Hopcraft and Morgan[3] compared the caries prevalence among two cohorts of new Australian army recruits (1996 and 2003). Among both cohorts, caries experience increased with increasing age. However, as compared to the 1996 cohort, DMFT values among the 2003 cohort declined by approximately 25 percent across all age groups (17 to 35 years). The decline was greatest among 17-20-year-olds (32%) and least among 31-35-year-olds (22%). Moreover, the percentage of recruits presenting with no caries experience (DMFT = 0) was greater in 2003 than in 1996 across all age groups.

Menghini and colleagues[36] compared caries prevalence among Swiss army recruits in 1996 and 2006. The authors reported a 37 percent decrease in mean DM6FT values [the sum of carious, missing (first molars only) and filled teeth] (DM6FT: 4.95 to 3.11) among all personnel, and an increase in the percentage of caries-free recruits from 15.6 percent to 27.9 percent between 1996 and 2006.

While a decline in caries prevalence is evident in other military studies, comparable findings among U.S. recruits have not been reported. Among incoming U.S. military recruits (median age 19) in 2008, 72% required at least one dental restoration due to caries, and 18% presented for initial examination with 7 or more untreated caries lesions.[39, 40] According to data from the Tri-Service Center for Oral Health Studies (TSCOHS), the proportion of recruits reporting with no existing caries lesions at in-processing increased from 20.6% in 1994 to 34.4% in 2000, but declined to 28.0% in 2008. Moreover, the proportion of incoming recruits in Department of Defense (DoD)

Dental Readiness Class 3 (i.e., not fit for deployment) increased from 47.5% in 2000 to 52.4% in 2008.

U.S. military personnel represent a subset of the greater population, but unique demographics are evident. While 50.7% of the U.S. population is female,[41] 14.3% of the active duty force and 15.5% of officers are female.[42] By race and ethnicity, 26.6% of the general population identify themselves as minority (black or African American, Asian, American Indian or Alaska native, Native Hawaiian or other Pacific Islander, multi-racial, or other/unknown), while 29.7% of the military consider themselves minority. By education level, 25.1% of individuals in the general population of at least 18 years of age have a Bachelors degree or higher. In contrast, the majority of military officers (86.0%) have a Bachelors degree or higher; however, only 4.6% of enlisted personnel, well below the U.S. average, have completed a college degree. Clearly, the demographic profile of US service members differs, in many aspects, from that of the general population.

Anecdotal observations have raised concerns about the possibility of increased caries experience among students of all three military service academies during their undergraduate training. A review of the dental literature revealed only one longitudinal study, published in 1993, of dental caries incidence among college-aged students in residential educational settings. Stahl and Katz[43] reported that 42% of U.S. Coast Guard Academy cadets (n = 164) developed caries lesions on occlusal surfaces between the initial examination in 1985 and the exit examination performed in 1988. Additionally, the study noted that prior dental history and socioeconomic status were poor predictors of caries incidence.

Little, if any, current information is available about caries experience among college-aged students in general, or among students enrolled in the U.S. military service academies in particular. Therefore, the purpose of this study is to assess the 4-year caries incidence (retrospective, from matriculation to graduation) among United States Naval Academy Midshipman. In addition, correlations between several possible risk indicators and caries incidence will be assessed. This study will serve as a comparison for data gathered at the U.S. Army and Air Force service academies, and as a baseline to assess trends in caries prevalence and incidence among future cohorts of students at the U.S. military service academies, as well as non-military residential educational settings.

CHAPTER II: MATERIALS AND METHODS

Subjects. For this collaborative research with the Tri-Service Center for Oral Health Studies (TSCOHS), Bethesda, MD, we sought to review the dental records of a random sample of 300 midshipmen from the 2011 graduating class at the U.S. Naval Academy in Annapolis, MD. All midshipmen in the 2011 senior class who entered the Naval Academy in 2007, with no prior military service or previous enrollment in the U.S. Naval Academy Preparatory School, and whose dental records were maintained at the Naval Health Clinic Annapolis were eligible for inclusion in the study. To ensure the subjects' anonymity, we assigned a unique identification code to each subject. No personally identifiable protected health information or subject identifiers during the record examination process were utilized. Subject records were not linked in any way to the database.

Sample Size Determination and Random Selection. Sample size was calculated using an online database web survey software program (Raosoft®, Inc., 6645 NE Windermere Road, Seattle, WA 98115; www.Raosoft.com). Based on a population size of 1150 students, 5% margin of error, 95% confidence level, and a response distribution of 50%, the software calculated a sample size of 289. For ease in statistical calculations, we chose to increase the sample size to 300. Patient records were randomly selected from a numbered alphabetical class roster using a list of numbers produced by a random number generator (Dr. Mads Haahr, School of Computer Science and Statistics, Trinity College, Dublin 2, Ireland; www.random.org).

Examiners. Five calibrated examiners, four from Naval Postgraduate Dental School (M.S.S., K.E.D., T.C.H., B.M.R.) and one from TSCOHS (T.M.L.) traveled to Naval Health Clinic Annapolis during May 2011 to conduct record reviews. To ensure data integrity, the data recorded for every fifth subject were verified by a second examiner; any differences were resolved via forced consensus, utilizing a third examiner when necessary. If more than three recording discrepancies were found in an individual patient chart, subsequent charts were reviewed until no discrepancies were observed.

Definition of Caries Risk Status. Caries risk status at matriculation was based on current U.S. Navy Oral Disease Risk Management (ODRM) guidelines (Appendix A).[44] Low-risk patients were defined as presenting with 0 caries lesions (D component of DMFT). Moderate-risk patients were defined as presenting with 1-2 caries lesions, and high-risk patients were recorded as presenting with 3 or more caries lesions.

Variables for Analysis. All subjects received annual dental examinations beginning with the initial examination upon matriculation into the Naval Academy. The initial examination and each periodic dental examination included a clinical and radiographic assessment, using new or existing radiographs, as indicated. In this retrospective review of dental records, we collected and analyzed data from 300 U.S. Naval Academy midshipmen from the date of matriculation in 2007 through the final dental examination prior to graduation in 2011.

Gender, age, and tobacco use were determined from patient-reported information recorded during the initial and subsequent dental examinations. Periodontal status was determined from the Periodontal Screening and Recording Index

(PSR) scores recorded by the examining dentist during the initial and subsequent examinations. Calculations of the number of active caries lesions, the number of diseased, missing, or filled surfaces (DMFS), and the number of diseased, missing, or filled teeth (DMFT) at matriculation were based on the findings recorded at the initial dental examination. Annual caries incidence was determined by the number of caries lesions documented at each examination and the number of restorations placed between examinations (example calculations in Appendix B). Total caries incidence was determined by addition of mean annual caries incidence calculated at the third- and fourth-year examinations.

Statistical Analysis. We analyzed data to determine the following:

- What is the mean prevalence of dental caries (DMFS, DMFT, and incipient surfaces), at each examination, among Naval Academy midshipmen?
    - Do significant differences exist among caries risk groups?
    - What is the change in DMFS, DMFT, and incipient surfaces within each risk group from the initial (matriculation) through the final examination?
- What is the mean annual caries incidence?
- What is the total, four-year dental caries incidence?
- Does the <u>annual</u> caries incidence change from Year 1 to Year 4?
- Which indicators for caries incidence are present within the midshipmen population?

Differences in caries prevalence (mean DMFS, DMFT, 'D' surfaces, and incipient surfaces) among caries risk groups at each examination were calculated by one way ANOVA and Tukey HSD post hoc tests. Within each caries risk group, repeated measures ANOVA was employed to assess differences in DMFS, DMFT, 'D' surfaces, and incipient surfaces between examinations. Paired samples *t*-Tests were utilized to compare caries incidence between examinations for each group. Significant indicators for caries incidence were determined by stepwise linear regression analyses. Statistical analyses were accomplished using Statistical Package for the Social Sciences (SPSS) Version 18 computer software. All statistical significance levels were set at $\alpha = 0.05$.

Human Subject Use. The protocol for this study was reviewed and approved by the Institutional Review Boards (IRB) for the Naval Postgraduate Dental School and U.S. Naval Academy (National Naval Medical Center IRB), and the Uniformed Service University of the Health Sciences (USUHS). All investigators completed the "Collaborative IRB Training Initiative" (CITI) to ensure compliance with the requirement for protection of human research subjects.

CHAPTER III: RESULTS

The sample size consisted of 300 Naval Academy midshipmen from the 2011 graduating class. Findings were recorded based on three examinations: initial (E1), third-year (E2), and fourth-year (E3). The mean duration between the examinations is recorded in Table 1.

Table 1. Mean (± standard deviation) duration between examinations.

Examination Period	Mean (years)	Minimum (years)	Maximum (years)
E1 - E2	2.34 (± 0.18)	1.49	3.24
E2 - E3	0.87 (± 0.15)	0.40	1.70
Total (E1 - E3)	3.19 (± 0.12)	2.17	3.76

The gender distribution included 239 males (79.7%) and 61 females (20.3%); median age was 18 years (range = 17 - 22). The initial examination (E1) identified 66.0% of the patients as low-risk (n = 198), 16.7% moderate-risk (n = 50), and 17.3% high-risk (n = 52) (Table 2). By the fourth-year dental examination (E3), the proportion of low-risk patients had declined to 53.0% (n = 159), while high-risk had risen to 29.0% (n = 87).

Table 2. Distribution of caries risk status classifications (%) at each examination.

Examination	Caries Risk Status (n = 300)		
	Low (%)	Moderate (%)	High (%)
E1	66.0 (198)	16.7 (50)	17.3 (52)
E2	52.3 (157)	21.0 (63)	26.7 (80)
E3	53.0 (159)	18.0 (54)	29.0 (87)

Changes in individual caries risk status from E1 to E3 are indicated in Tables 3 and 4. In general, patients identified at E1 as low- or high-caries risk tended to remain within the same risk category at E3 (Table 3: Low-risk = 72.2%; High-risk = 76.9%). Only 13.7% of low-risk patients shifted to high-risk, while only 7.7% of high-risk patients became low-risk, by their final dental examinations. In addition, we observed that 62.6% (124/198) of low-risk (i.e., caries-free) patients remained caries-free at each subsequent examination (Table 4). Conversely, 71.2% (37/52) of high-caries risk patients remained high-risk, presenting with three or more caries lesions at each examination. Among caries-free patients, exactly half (99/198) presented at E1 with no previous restorations (hence, DMFS = 0), while the other half presented with one or more restorations ('D' = 0, but DMFS ≥ 1). As seen in Table 4, by the E3 examination, the number of patients with DMFS = 0 declined from 33.0% of the population (99/300) to 24.0% (72/300). However, the number of low-risk patients with DMFS ≥ 1 who remained caries-free at E3 declined even further, from 33.0% (99/300) at E1 to 17.3% (52/300) by the E3 examination.

Table 3. Change in caries risk status from E1 to E3.

Low Caries Risk at E1 (n = 198)	
Remained low caries risk through E3	72.2% (143)
Changed to moderate risk at E3	14.1% (28)
Changed to high risk at E3	13.7% (27)
Moderate Caries Risk at E1 (n = 50)	
Remained moderate caries risk through E3	36.0% (18)
Changed to low risk at E3	24.0% (12)
Changed to high risk at E3	40.0% (20)
High Caries Risk at E1 (n = 52)	
Remained high caries risk through E3	76.9% (40)
Changed to low caries risk at E3	7.7% (4)
Changed to moderate caries risk at E3	15.4% (8)

Table 4. Fate of low- and high-caries risk patients from E1 to E3.

Caries Risk Status[1]	E1	E2	E3
Low Caries Risk (DN = 0)	66.0% (198)	46.3% (139)	41.3% (124)
DMFS = 0 (DN = 0; F = 0)	33.0% (99)	25.0% (75)	24.0% (72)
DMFS ≥ 1 (DN = 0; F ≥ 1)	33.0% (99)	21.3% (64)	17.3% (52)
High Caries Risk (DN ≥ 3)	17.3% (52)	14.0% (42)	12.3% (37)

[1] D = decayed, N = incipient, F = filled surfaces.

Variables describing caries prevalence (mean DMFS, DMFT, 'D' surfaces, and incipient surfaces) at each examination are noted in Tables 5a and 5b. For each of these four variables, one way ANOVA and Tukey HSD post hoc tests revealed statistically significant differences among all three risk groups (Low < Moderate < High; all $p < 0.05$) at each examination, with the following exceptions:

1) There were no significant differences in DMFS scores between the low- and moderate-risk groups at either E1 or E2 ($p = 0.303$ and 0.060, respectively).

2) No significant difference was noted between low- and moderate-risk groups for incipient surfaces at E2 ($p = 0.165$).

Within each caries risk category, repeated measures ANOVA revealed significant increases in DMFS, DMFT, and incipient surfaces from E1 to E3 (Tables 5a and 5b). The exception was noted among decayed ('D') surfaces for the high-risk group. In general, for each variable, the increase was greater from E1 to E2 than from E2 to E3. Moreover, increases in DMFS and DMFT were greater for moderate- and high-risk patients than for low-risk. For example, DMFS increased 35.3% and 32.8% for moderate- and high-risk patients, respectively, and 17.8% for low-risk patients.

Table 5a. Caries prevalence data (DMFS, DMFT) by caries risk status at each examination.

Examination	DMFS[1]			DMFT[1]		
	Low	Mod	High	Low	Mod	High
E1	4.10[a]	5.72[a]	10.31	2.06	3.46	5.81
E2	4.48[b]	7.10[b]	12.33	2.31	4.28	6.67
E3	4.83	7.74	13.69	2.79	5.30	8.10
Sig. [2]	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

[1] One way ANOVA and Tukey HSD post hoc tests. Low < Moderate < High at each exam; all p <0.05), except [a] (p = 0.303), and [b] (p = 0.06).

[2] Repeated measures ANOVA and Tukey HSD post hoc tests. E1 < E2 < E3 within each risk category; all p < 0.001).

Table 5b. Caries prevalence data (decayed 'D' and incipient surfaces) by caries risk status at each examination.

Examination	'D' Surfaces[1]			Incipient Surfaces[1]		
	Low	Mod	High	Low	Mod	High
E1	0	0.98	4.37[d]	0	0.44	2.65
E2	0.36	1.66	5.29[d]	0.53[c]	1.24[c]	3.15
E3	0.48	1.88	5.29[d]	0.51	1.60	4.08
Sig.[2]	< 0.001	0.021	0.398	< 0.001	0.005	0.013

[1] One way ANOVA and Tukey HSD post hoc tests. Low < Moderate < High at each exam (all p <0.05), except [c] (p = 0.165).

[2] Repeated measures ANOVA and Tukey HSD post hoc tests. E1 < E2 < E3 within each risk category; all p < 0.021, except [d] (p = 0.398).

Caries incidence from E1 to E2 and from E2 to E3 was calculated based on the number of caries lesions documented at each examination and the number of restorations placed between examinations (Table 6; calculations in Appendix B). At E2, a significant difference was noted between the low- and moderate-risk groups ($p = 0.028$) and the low- and high-risk groups ($p < 0.001$). No significant difference was determined between the moderate- and high-risk groups ($p = 0.120$). At E3, a significant difference was noted only between the low- and high-risk groups ($p < 0.001$); there were no significant differences between low- and moderate-risk groups ($p = 0.096$) or moderate- and high-risk groups ($p = 0.084$). However, when assessing total caries incidence (E1 to E3), statistically significant differences were noted among all risk groups (all $p < 0.015$). Compared to low-risk patients, total caries incidence was 2.3X greater for moderate-risk and 3.7X greater for high-risk patients (Figure 1).

Paired samples *t*-Tests were employed to compare differences in caries incidence between E2 and E3 for each risk group (Table 6). No significant differences were noted between E2 and E3 for the low-risk ($p = 0.439$), moderate-risk ($p = 0.488$), or the high-risk groups ($p = 0.938$).

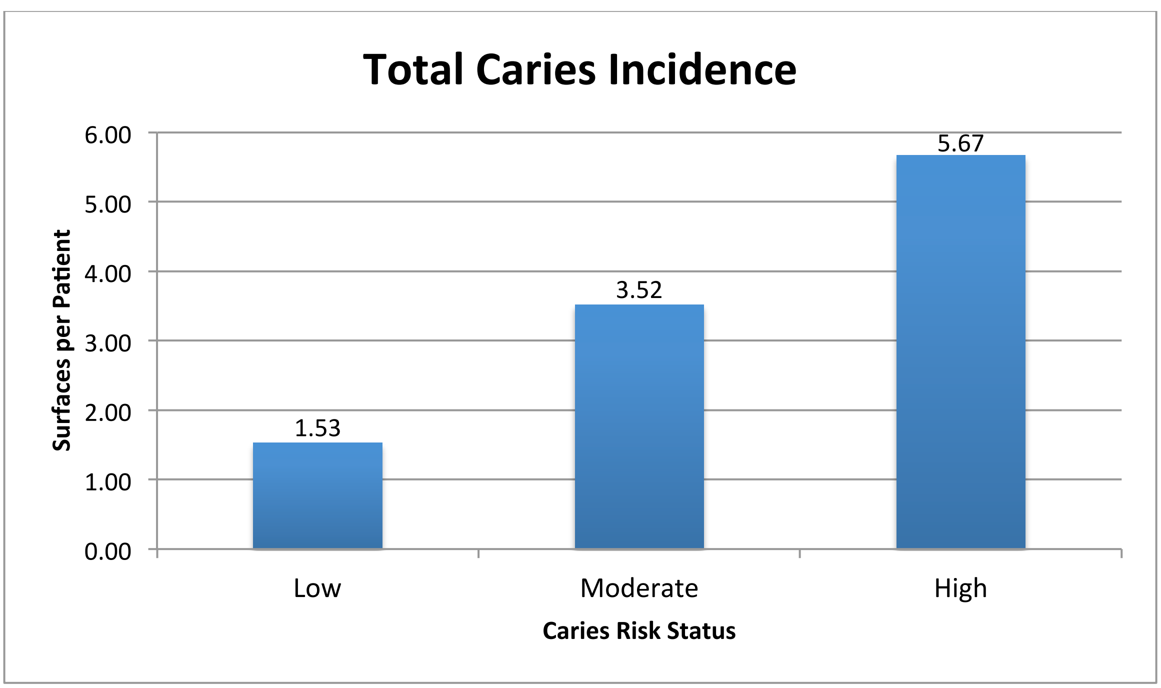
Table 6. Caries incidence (surfaces per patient) by caries risk status at each examination.

Examination	Caries Incidence (surfaces per patient)		
	Low[2]	Moderate[2]	High[2]
E1	--	--	--
E2[1]	0.98[a]	2.26[b]	3.48[b]
E3[1]	0.54[c]	1.26[cd]	2.19[d]
Total Caries Incidence[1]	**1.52[e]**	**3.52[f]**	**5.67[g]**

[1] One way ANOVA and Tukey HSD. Identical letters designate non-significant differences among risk groups at each examination and in total caries incidence ($p > 0.05$).

[2] Paired Samples *t*-Test. No significant difference in caries incidence noted within each risk group from E2 to E3 (all $p > 0.05$).

Figure 1. Total caries incidence (surfaces per patient) by caries risk status.



Stepwise linear regression analyses were performed to determine the most significant predictors for caries incidence (Table 7). Potential predictors included decayed surfaces, decayed teeth, incipient surfaces, filled surfaces, DMFS, and DMFT, as noted during the initial (E1) examination. Among all groups combined, decayed surfaces was the single strongest predictor of total caries incidence ($p < 0.001$), with decayed plus incipient surfaces providing the strongest model for predicting total caries incidence ($p < 0.001$). These predictors were also significant in the high-risk category (decayed surfaces: $p = 0.010$; decayed surfaces plus incipient surfaces: $p = 0.004$). Among the low-risk group, filled surfaces proved to be the strongest predictor ($p = 0.047$). Among the moderate-risk group, no significant predictors for caries incidence could be determined. No other variables approached statistical significance in predicting caries incidence among the individual caries risk groups.

Table 7. Most significant predictors for caries incidence.[1]

Caries Risk Category	Strongest Predictor	Significance Level
Low	Filled surfaces	0.047
Moderate	No significant predictors[*]	--
High	Decayed surfaces Decayed surfaces plus incipient surfaces	0.010 0.004
All Groups	Decayed surfaces Decayed surfaces plus incipient surfaces	< 0.001 < 0.001

[1]Stepwise linear regression analyses ($\alpha = 0.05$).

[*]No significant predictors (Decayed, incipient, or filled surfaces, decayed teeth, DMFS, or DMFT) were determined in the analysis.

CHAPTER IV: DISCUSSION

This study was performed to assess caries prevalence and incidence among Midshipmen at the U.S. Naval Academy. Dental examinations were performed upon matriculation and repeated during the students' third and fourth years. The assessment was implemented by means of a record review of the 2011 graduating class following completion of the final, fourth-year examination. Data were gathered to determine DMFS, DMFT, decayed surfaces, incipient surfaces, and caries incidence. Each record selected was categorized by caries risk status prior to statistical analysis.

In general, analysis of the data revealed statistically significant differences among all three risk groups (Low < Moderate < High) at each examination for all five outcome variables. However, three exceptions were noted: (1) there was no significant difference in incipient lesions between low- and moderate-risk groups at the second examination; and (2) there were no significant differences in DMFS between low- and moderate-risk groups at both E1 and E2.

When assessing the changes in DMFS, DMFT, decayed surfaces, and incipient surfaces from the first-year through fourth-year examinations, significant increases were noted for each caries risk group. An exception was noted for decayed surfaces within the high-risk group. Increases in DMFS, DMFT, decayed surfaces, and incipient surfaces were, in general, greater for the moderate- and high-risk categories than for the low-risk population. For example, the DMFS increased by 17.8%, 35.3%, and 32.8% over the duration of the study in the low-, moderate-, and high-risk groups, respectively.

During our initial review of the patient records, concerns arose regarding the ability to track incipient lesions for each patient over the course of the study. Our concerns were twofold: (1) inconsistent charting of incipient lesions in the dental records, and (2) inconsistencies among providers in the radiographic and clinical diagnosis of incipient lesions during the examinations. To determine the impact of incipient lesions on caries risk status, we assigned caries risk status to each patient in two ways: (1) first, by counting, or including, incipient lesions in the determination of caries risk, as reported in the Results section; and (2) second, by ignoring the presence of incipiencies, thus excluding them from the risk status determination, even though excluding incipient lesions from the caries risk designation is not consistent with the current American Dental Association (ADA) guidelines for establishing an individual patient's caries risk status. This yielded a noticeable change in the distribution of caries risk, as well as DMFS, DMFT, and caries incidence calculations, at each examination.

When incipient lesions were included in the risk designation, DMFS, DMFT, and total caries incidence were generally lower for each risk group at each examination. We noted the following trends:

1) DMFS scores were lower by an average of 6.3%, 14.0%, and 19.5% over all three examinations for the low-, moderate-, and high-risk groups, respectively.
2) DMFT scores were lower by an average of 9.3%, 6.7%, and 21.0% for the low-, moderate-, and high-risk groups, respectively.

3) Total caries incidence was 16.5%, 5.9%, and 22.7% lower for the low-, moderate-, and high-risk groups, respectively.

The reason for the overall decline in DMFS, DMFT, and caries incidence is attributable to the redistribution of subjects among the three caries risk groups. When incipient lesions were included in the risk assignment, we noted an increase in the proportion of high caries-risk patients, and a corresponding decrease in the proportion of low- and moderate-risk patients. This phenomenon appears to be the result of shifting low- and moderate-risk patients into higher risk categories based solely on the presence of incipient lesions. These shifts effectively lowered the mean DMFS, DMFT, and caries incidence scores for each caries risk group. This trend was especially noteworthy in the high caries-risk group.

Review of the caries risk distribution (Table 2) at each examination revealed that the number of low caries risk patients declined from E1 (66.0%) to E2 (52.3%), then remained unchanged from E2 to E3 (53.0%). The data also revealed a corresponding increase in the number of high caries risk patients throughout the study, with the greatest increase occurring between the first and second examinations. While an explanation for the increasing number of high caries risk patients is certainly multi-factorial, the sudden change in lifestyle that accompanies a significant change of environment (e.g., beginning a new collegiate education) may be the single most important contributing factor.

Analogous to our findings on caries prevalence, we noted statistically significant differences in caries incidence among all three caries risk groups. It is important to note that, as compared to the low-risk group, total caries incidence was twice as great for moderate-risk and nearly four times greater for high-risk patients. While these near-linear increases were somewhat unexpected, the data are consistent with previous reports suggesting that dental caries predictably concentrates among higher risk patients, while remaining low among patients with minimal prior caries experience.[14,15,34,35] Interestingly, we observed that caries incidence actually decreased between the E2 and E3 examinations, as compared to the E1 – E2 examination interval, among all risk groups. However, the decrease was statistically significant for only the moderate risk group (Table 6). This observation is most likely attributable to two primary factors: (1) the longer time period between the E1 and E2 examinations (2.34 years) than between E2 and E3 (0.87 years); and (2) the implementation of dental care while enrolled at the Naval Academy.

The focus of dental caries among a select, high-risk population reflects the disparity in caries experience that has been noted in large-population studies such as NHANES[19-23] and Health, United States, 2009.[25] Current epidemiologic evidence indicates that dental caries tends to concentrate among relatively few individuals; this may distort overall caries prevalence and incidence rates of the greater population.[19,20,22,23,30-33] These studies provide a background understanding that dental caries is not shared equally among the entire population; this study echoes these findings.

Support for this argument is evident in two particular sets of data within this study: caries incidence and changes in caries risk status. First, as previously stated, total caries incidence was more than twofold greater among moderate-risk patients and nearly fourfold greater among high-risk patients, as compared to the low-risk group. The data suggest that high caries risk patients, representing only 17.3% of midshipmen at matriculation, can expect to develop nearly four times more dental caries than low-risk patients, and thus require the vast majority of restorative dental treatment. Second, the majority of patients (76.9% of high-risk and 72.2% of low-risk) remained in their initial caries risk category through their final dental examinations. Among low caries risk patients, only 14.1% shifted to moderate risk and 13.7% changed to high caries risk by the final examination. Moreover, only 7.7% of high-risk patients were low-risk at their final examinations. Clearly, low-risk patients displayed a tendency to remain low caries risk, while high-risk patients tended to remain high caries risk. Together, these data suggest that individuals will remain in their initial caries risk categories, and may expect to experience dental caries at significantly greater rates if they are identified as moderate- or high-risk.

The time interval between dental examinations was a limitation that was beyond the control of this study. While our study encompassed the first- through fourth-year dental examinations, the actual mean time period between the initial and final examinations was 3.19 years. This was due, in part, to the clinic's need to conduct fourth-year examinations by January 2011 in order to ensure completion of any necessary treatment prior to graduation in May 2011. Moreover, for logistic and administrative reasons (e.g., limited patient availability, clinic manpower shortages, etc.), dental examinations were not performed during the second academic year. This resulted in mean intervals of 2.34 years between the first- and third-year examinations, and 0.87 years between the third- and fourth-year examinations. Equal intervals, combined with a second-year examination, may have provided an opportunity to more precisely assess changes in caries prevalence and incidence throughout the study.

A second limitation of our study is the lack of a prospective experimental design. Because the study was, by intention, a retrospective record review, a universal calibration among the examiners providing the annual dental examinations could not be performed. This manifested most notably in the variable charting of incipient caries lesions. As stated previously, the lack of consistent diagnosis and recording of incipient lesions served as the primary justification for conducting our analyses in two ways: first, by including or counting, and second, by excluding or ignoring incipient lesions when determining patient caries risk status.

Furthermore, risk factors such as existing multi-surface restorations, presence of exposed root surfaces, poor oral hygiene, and individual diet cannot be readily recorded on, or interpreted from, the standard U.S. Navy annual dental examination form. In addition, we could not account for race and socioeconomic factors, as they are not components of the annual Navy dental examination form, despite previous studies having shown elevated caries experience among individuals of low socioeconomic status and racial minorities.[3-5,30-33] As a result, these additional risk factors could not be utilized to establish caries risk status in this study. Including known risk factors may provide a more accurate estimate of caries risk in this population, which may increase the proportion of moderate- and high-caries patients in the overall risk distribution.

Finally, this study attempted to determine the most significant predictors for caries incidence for each caries risk category, as well as the total population, based on caries prevalence data obtained from the initial dental examination (Table 7). Possible predictors included DMFS, DMFT, decayed surfaces, decayed teeth, filled surfaces, incipient surfaces, and decayed surfaces plus incipient surfaces. The analysis revealed that filled surfaces proved to be the single strongest predictor for caries incidence among the low-risk group. This is supported in our data, as caries-free patients with one or more previously filled surfaces were less likely than those with no previous restorations (i.e., DMFT = 0) to remain caries-free through the course of the study (Table 4). This suggests that the presence of filled surfaces, even amongst a low-risk group, may influence caries incidence in this population. Interestingly, our linear regression analysis established no significant predictors in the moderate-risk group. The reason for this result is unknown. Among high-risk patients, decayed surfaces and decayed surfaces plus incipient lesions proved to be the strongest predictors of future caries incidence. This result was repeated when determining the strongest predictors for all risk groups, as decayed surfaces and decayed surfaces plus incipient lesions proved to be the strongest predictors for expected caries incidence. It is not surprising that the presence of active disease at the initial examination could predict future caries incidence among this population. This is consistent with the assertion that prior caries history and current disease status reliably predict future caries experience.[14,15,34,35] This may translate clinically by placing a strong emphasis on the importance of aggressive caries risk management protocols for high-risk young adult populations, since, as determined in this study, they may potentially display a nearly four times greater caries incidence during post-secondary education.

The importance of incipient surfaces as a predictor for future caries incidence in this population became apparent when we ignored incipient lesions in determining caries risk status. With this approach, incipient surfaces proved to be the single strongest factor in predicting caries incidence among the low- and moderate-risk groups. This result highlights the importance of incipient lesions in this population, and illustrates the predictive strength of incipiencies in the progression to outright caries lesions. This carries direct clinical application, as incipient lesions need to be identified and treated by a combination of oral hygiene instruction, dietary modification, and remineralization therapy.[45] Our data suggest this is true for even low- and moderate-risk patients.

A secondary objective of this study was to provide data on caries rates and distribution among a military-specific cohort of college-aged students for comparison to various populations for which previous epidemiologic studies have been performed. Data for comparison are available from clinical examinations and record reviews of active-duty service members.

Bartoloni and colleagues'[1] investigation of caries risk among active duty Air Force personnel revealed a comparable distribution of low-, moderate-, and high-risk patients. They observed a downward trend in caries risk over the course of their study, a finding in direct opposition to that observed in our study. While the overall distribution of caries risk was comparable, some differences were noted (Table 2). In the Air Force study, the percentage of high-risk ranged from 11.0 to 7.6%, while in our study the percentage of high risk ranged from a high of 29.0% to a low of 17.3%. However, the distributions of low- and moderate-risk patients were similar. It should be noted that the Air Force population included both enlisted and officer personnel, while the current study included only a future officer population during their collegiate education. Furthermore, when assessing Air Force personnel of a comparable age (≤ 24 years of age), the percentage of high-risk patients was between 23.6 and 12.8%, which is similar to the percentage of high-risk midshipmen in this study. This appears to illustrate the importance of age when assessing caries risk distribution of a selected population.

In order to compare this future Naval officer cohort to an enlisted population of similar age, the TSCOHS Department of Defense 2008 Recruit Oral Health Survey provides clinical findings for a newly enlisted population across all U.S. military branches in 1994, 2000, and 2008.[39, 40] In the 2008 TSCOHS recruit study, 82.1% of the study population was between 18 and 24 years of age. In this study of Naval Academy midshipmen, the age range at matriculation was 17 to 22 years, with a median age of 18 years. The contrast in need for restorative treatment based on the presence of dental caries between the enlisted recruits and midshipmen is clear. Among the enlisted recruits, 20.6% in 1994, 34.4% in 2000, and 28.0% in 2008 presented as caries-free, requiring no restorative treatment. In contrast, among midshipmen entering the Naval Academy in 2007, 66.0% were caries-free.

While race, ethnicity, and socioeconomic status were not recorded in this study, they may represent additional factors that contribute to this disparity in restorative need between a newly recruited enlisted population and service academy midshipmen. Such factors are evident in Hopcraft's study of Australian Army recruits; individuals who had completed secondary school (year 12) displayed significantly lower caries experience (DMFT) than those who had completed fewer than year 12 of education.[3] In addition, the highest socioeconomic group exhibited significantly lower caries experience than the lowest socioeconomic group. Accounting for potential risk factors, such as race and socioeconomic status, in future epidemiologic studies of military service academies may provide a more comprehensive understanding of caries incidence and distribution among this young adult population.

CHAPTER V: CONCLUSION

Our study of the caries experience of Midshipmen at the U.S. Naval Academy adds to the body of knowledge suggesting that dental caries history and current disease status reliably predict future caries incidence in a young adult population. Support for this argument is evident in the caries prevalence data (DMFS and DMFT) and the caries incidence calculations. We found significant differences in DMFS and DMFT among all caries risk groups (low, moderate, and high) at each successive dental examination. Moreover, DMFS and DMFT values continually increased from the initial, matriculation examination through the final, fourth-year examination.

These results were echoed in the caries incidence data as well. We found a consistent, nearly linear increase in total caries incidence among the low-, moderate-, and high-risk groups. Caries incidence among moderate risk patients was more than double that of the low risk group, while high caries risk patients showed a nearly fourfold increase in caries incidence.

We were able to conclude the following from our retrospective record review of Midshipmen at the U.S. Naval Academy:

1. Caries prevalence and incidence were consistently greater for moderate- and high-risk patients.
2. The magnitude of increase in caries experience was greater for moderate- and high-risk patients.
3. Caries history and current disease status reliably predict future caries experience in this young adult population

To our knowledge, this is the first epidemiologic study in nearly 20 years to assess the caries experience of a young adult, residential college-attending population. The results of this study may provide insight into dental caries prevalence and incidence expectations among a college-specific cohort. Moreover, this study has provided the opportunity to evaluate dental caries experience at a U.S. military service academy. The implications are twofold: (1) serve as a baseline for future longitudinal cohort studies at military service academies; and (2) influence treatment policy by encouraging the early identification and treatment of high caries risk patients.

APPENDIX A

U.S. Navy Oral Disease Risk Management Guidelines

Caries Risk Status	Criteria
Low	No new incipient or cavitated primary or secondary caries lesions during current exam; **AND** No factors that may increase caries risk.
Moderate	One or two new incipient or cavitated primary or secondary caries lesions during current exam; **OR** No incipient or cavitated primary or secondary caries lesions during current exam, but presence of at least one factor that may increase caries risk.
High	Three or more new incipient or cavitated primary or secondary caries lesions during current exam; **OR** Presence of multiple factors that may increase caries risk.
Source: BUMED Instruction 6600.16A, 23 August 2010.[44]	

APPENDIX B

Calculation of Annual Mean Caries Incidence

Caries Incidence at E2 = Decayed surfaces at E2 – [Decayed surfaces at E1 – (Filled surfaces at E2 – Filled surfaces at E1)]

Caries Incidence at E3 = Decayed surfaces at E3 – [Decayed surfaces at E2 – (Filled surfaces at E3 – Filled surfaces at E2)]

Caries incidence (at E2, E3, and total caries incidence) was calculated for each individual patient based on the number of caries lesions documented at each examination and the number of restorations placed between examinations. Total caries incidence was determined by addition of the annual caries incidence calculated at the third- and fourth-year examinations. Mean caries incidence (at E2, E3, and total caries incidence) for each risk designation (low-, moderate-, and high-risk) was calculated based on the individual caries incidence for each patient within the assigned risk group.

<u>Step-by-step calculation for each patient (examples provided below):</u>

Exam 1 to Exam 2:	$F_{E2} – F_{E1} = F_0$ (# of original 'D' surfaces filled) $D_{E1} – F_0 = D_1$ (# of original 'D' surfaces carried over to Exam 2) $D_{E2} – D_1 = \mathbf{Inc_{E2}}$ (# of NEW 'D' surfaces between Exam 1 & Exam 2)
Exam 2 to Exam 3:	$F_{E3} – F_{E2} = F_1$ (# of 'D' surfaces filled between Exam 2 & Exam 3 $D_{E2} – F_1 = D_2$ (# of 'D' surfaces carried over to Exam 3) $D_{E3} – D_2 = \mathbf{Inc_{E3}}$ (# of NEW 'D' surfaces between Exam 2 & Exam 3)
Exam 1 to Exam 3:	$Inc_{E2} + Inc_{E3} = \mathbf{Inc_{tot}}$ (# of NEW 'D' surfaces from Exam 1 to Exam 3)

Example Calculations:

Patient identification number: 109 (Low caries risk)

EXAM	D	M	F
E1	**0**	**0**	**10**
E2	**0**	**0**	**10**
E3	**1**	**0**	**10**

D = Decayed surfaces (including incipient surfaces)
M = Missing surfaces
F = Filled surfaces

Exam 1 to Exam 2: 10 – 10 = 0 (# of original 'D' surfaces filled)
0 – 0 = 0 (# of original 'D' surfaces carried over to Exam 2)
0 – 0 = **0** (# of NEW 'D' surfaces between Exam 1 & Exam 2)

Exam 2 to Exam 3: 10 – 10 = 0 (# of 'D' surfaces filled between Exam 2 & Exam 3
0 – 0 = 0 (# of 'D' surfaces carried over to Exam 3)
1 – 0 = **1** (# of NEW 'D' surfaces between Exam 2 & Exam 3)

Exam 1 to Exam 3: 0 + 1 = **1** (# of NEW 'D' surfaces from Exam 1 to Exam 3)

Patient Identification number: 250 (High caries risk)

EXAM	D	M	F
E1	**9**	**0**	**5**
E2	**8**	**0**	**10**
E3	**16**	**0**	**10**

Exam 1 to Exam 2: 10 - 5 = 5 (# of original 'D' surfaces filled)
9 - 5 = 4 (# of original 'D' surfaces carried over to Exam 2)
8 - 4 = **4** (# of NEW 'D' surfaces between Exam 1 & Exam 2)

Exam 2 to Exam 3: 10 - 10 = 0 (# of 'D' surfaces filled between Exam 2 & Exam 3)
8 - 0 = 8 (# of 'D' surfaces carried over to Exam 3)
16 - 8 = **8** (# of NEW 'D' surfaces between Exam 2 & Exam 3)

Exam 1 to Exam 3: 4 + 8 = **12** (# of NEW 'D' surfaces from Exam 1 to Exam 3)

APPENDIX C

Codes for Data Collection Form

SURFACE STATUS CODES	
SOUND, NO RESTORATION	S
SEALANT	L
INCIPIENT CARIES	N
CARIES	C
RESTORED, SOUND	R
RESTORED, NOT SOUND (INCLUDES CARIES)	X
MISSING	M
IMPACTED (FULL OR PARTIAL)	I
IMPLANT	T
PONTIC (FIXED OR REMOVABLE)	P
FLUORIDE VARNISH	V

DENTAL EMERGENCY REASON CODES	
CARIES	1
TOOTH OR RESTORATION FRACTURE	2
PULPAL PAIN / LESION	3
PERIODONTAL PROBLEM	4
PERICORONITIS	5
TRAUMA	6
SOFT TISSUE LESION	7
TMD (INCL. CLENCHING/ BRUXISM)	8
OTHER	9

PATIENT LEVEL VARIABLES	DEFINITION
ID	Unique numeric identifier **(001 - 300)**.
SEX	Male **(M)** or Female **(F)**
1_AGE	Age of subject at time of first exam. (2_AGE at 2nd Exam, etc.)
1_EX_DT	First Exam Date. **(dd/mm/yyyy)** (2_EX_DT 2nd Exam Date, etc.)
1_TXA_DT	First Treatment Appointment Date. **(dd/mm/yyyy).**
1_CIGS	Cigarette use, Yes **(Y)** or No **(N)** at time of first exam.
1_DIP	Smokeless tobacco use, Yes **(Y)** or No **(N)** at time of first exam.
1_SEXT_1	PSR Score **(0 - 4)** for Sextant 1 at time of first exam.
1_SEXT_2	PSR Score **(0 - 4)** for Sextant 2 at time of first exam.
1_SEXT_3	PSR Score **(0 - 4)** for Sextant 3 at time of first exam.
1_SEXT_4	PSR Score **(0 - 4)** for Sextant 4 at time of first exam.
1_SEXT_5	PSR Score **(0 - 4)** for Sextant 5 at time of first exam.
1_SEXT_6	PSR Score **(0 - 4)** for Sextant 6 at time of first exam.
1_EX_PRO	Number of **PRO**phys after **1**st **Exam**
	(**2_EX_PRO** = Number of prophys after the second exam, etc)
1_EX_FA	Number of **F**luoride **A**pplications after **1**st **Exam**
	(**2_EX_FA** = Number of fluoride applications after the second exam, etc)

TOOTH VARIABLE EXAMPLES	DEFINITION	
1E_T1_C	At the first exam **(1E)**, the Dental Class **(C)** for tooth 1 **(T1)**	
1A_T1_C	At the treatment appointment **(1A)**, the Dental Class **(C)** for tooth 1 **(T1)**	
1E_T1_M	At the first exam **(1E)**, the surface status of Tooth 1 **(T1)** for the mesial surface **(M)**	
1A_T1_M	At the first treatment appointment **(1A)**, the surface status of Tooth 1 **(T1)** for the mesial surface **(M)**	
1E_T1_O	At the first exam **(1E)**, the surface status of Tooth 1 **(T1)** for the occlusal surface **(O)**	
1A_T1_O	At the first treatment appointment **(1A)**, the surface status of Tooth 1 **(T1)** for the occlusal surface **(O)**	
1E_T1_D	At the first exam **(1E)**, the surface status of Tooth 1 **(T1)** for the distal surface **(D)**	
1A_T1_D	At the first treatment appointment **(1A)**, the surface status of Tooth 1 **(T1)** for the distal surface **(D)**	
1E_T1_F	At the first exam **(1E)**, the surface status of Tooth 1 **(T1)** for the facial surface **(F)**	
1A_T1_F	At the first treatment appointment **(1A)**, the surface status of Tooth 1 **(T1)** for the facial surface **(F)**	
1E_T1_L	At the first exam **(1E)**, the surface status of Tooth 1 **(T1)** for the lingual surface **(L)**	
1A_T1_L	At the first treatment appointment **(1A)**, the surface status of Tooth 1 **(T1)** for the lingual surface **(L)**	
1DED_T1	First dental emergency date **(1DED)** for Tooth 1 **(T1)**	**Date Format: dd/mm/yyyy**
1DER_T1	First dental emergency reason **(1DER)** for Tooth 1 **(T1)**	**Use Emergency Reason Codes**

APPENDIX D

Data Collection Form (Partial Example)

Data collection was performed from tooth #1 through #32 for each subject selected for the record review. The following excerpt includes teeth #1-3 for subjects identified as #1 through #10. Codes for data collection are presented in Appendix C.

ID	001	002	003	004	005	006	007	008	009	010
SEX	M	F	F	F	M	F	M	F	F	M
1_AGE	18	18	17	18	17	18	18	18	18	18
1E_T1_M	M	I	M	M	I	M	M	M	S	I
1E_T1_O	M	I	M	M	I	M	M	M	R	I
1E_T1_D	M	I	M	M	I	M	M	M	S	I
1E_T1_F	M	I	M	M	I	M	M	M	S	I
1E_T1_L	M	I	M	M	I	M	M	M	S	I
1E_T2_M	S	S	S	S	S	S	S	S	S	N
1E_T2_O	R	S	R	S	S	S	S	S	R	X
1E_T2_D	S	S	S	S	S	S	S	S	S	S
1E_T2_F	S	S	S	S	S	S	S	S	S	S
1E_T2_L	S	S	S	S	S	S	S	S	S	C
1E_T3_M	N	S	S	S	S	S	S	S	S	N
1E_T3_O	S	S	R	S	S	R	S	S	X	X
1E_T3_D	S	S	S	S	S	S	S	S	S	S
1E_T3_F	S	S	S	S	S	S	S	S	S	S
1E_T3_L	S	S	S	S	S	S	S	S	S	S

REFERENCES

1. Bartoloni JA, Chao SY, Martin GC, Caron GA. Dental caries risk in the U.S. Air Force. *J Am Dent Assoc* 2006; 137(11): 1582-1591.
2. Cohen ME, Rocha T, Cecil JC, McCarthy TP. Dental recall based on caries risk. *Mil Med* 1983; 148(12): 928-931.
3. Hopcraft M, Morgan MV. Dental caries experience in Australian Army recruits 2002-2003. *Aust Dent J* 2005; 50(1): 16-20.
4. Hopcraft M, Morgan M. Dental caries experience in a young adult military population. *Aust Dent J* 2003; 48(2): 125-129.
5. Brown LJ, Swango PA. Trends in caries experience in U.S. employed adults from 1971-74 to 1985: cross-sectional comparisons. *Adv Dent Res* 1993; 7(1):52-60.
6. Brown JL, Wall TP, Lazar V. Trends in caries among adults 18-45 years old. *J Am Dent Assoc* 2002; 133(7): 827-834.
7. Brunelle JA, Carlos JP. Changes in the prevalence of dental caries in U.S. schoolchildren, 1961-1980. *J Dent Res* 1982; 61 (spec iss): 1346-51.
8. Mejare I, Stenlund H, Zelezny-Holmlund C. Caries incidence and lesion progression from adolescence to young adulthood: a prospective 15-year cohort study in Sweden. *Caries Res* 2004; 38(2): 130-141.
9. Stenlund H, Mejare I, Kallestal C. Caries rates related to approximal caries at ages 11-13: a 10-year follow-up study in Sweden. J Dent Res 2002; 81(7): 455-458.

10. Mejare I, Kallestal C, Stenlund H. Incidence and progression of approximal caries from 11 to 22 years of age in Sweden: a prospective radiographic study. *Caries Res* 1999; 33(2): 93-100.

11. Pitts, NB. Monitoring of caries progression in permanent and primary posterior approximal enamel by bitewing radiography. *Community Dent Oral Epidemiol* 1983; 11(4): 228-235.

12. Powell LV. Caries prediction: a review of the literature. *Community Dent Oral Epidemiol* 1998; 26(6): 361-371.

13. Newbrun E, Leverett D. Risk assessment dental caries working group summary statement. In Bader JD, ed. Risk assessment in dentistry: Proceedings of a conference. Chapel Hill: University of North Carolina School of Dentistry Department of Dental Ecology, 1990; pp. 304-305.

14. Adler P. Correlation between dental caries prevalences at different ages. *Caries Res* 1968; 2(1):79-86.

15. Birkeland J, Broch L, Jorkjent L. Caries experience as a predictor for caries incidence. *Community Dent Oral Epidemiol* 1976; 4(1):66-69.

16. Zero DT, Fontana M, Martinez-Mier EA, Ferreira-Zandona A, Ando M, Gonzalez-Cabezas C, Bayne, S. The biology, prevention, diagnosis, and treatment of dental caries: scientific advances in the United States. *J Am Dent Assoc* 2009; 140(Suppl 1): 25S-34S.

17. Featherstone, JDB. The science and practice of caries prevention. *J Am Dent Assoc* 2000; 131(7): 887-899.

18. Fletcher RH, Fletcher SW, Wagner EH. Clinical Epidemiology- The Essentials, 2nd ed. Williams and Wilkins, Baltimore, MD 1988; pp. 77-78.

19. U.S. Public Health Service, National Institute of Dental Research. The prevalence of dental caries in United States children, 1979-1980. Washington, DC: Government Printing Office; 1980. NIH Publication No. 82-2245.

20. U.S. Public Health Service, National Institute of Dental Research. Oral health of United States adults: national findings. Washington, DC: Government Printing Office; 1987. NIH Publication No. 87-2868.

21. Brunelle JA, Carlos JP. Recent trends in dental caries in U.S. children and the effects of water fluoridation. *J Dent Res* 1990; 69(Spec Iss):723-727.

22. U.S. Public Health Service, National Institute of Dental Research. Oral health of United States children, Washington, DC: Government Printing Office; 1989. NIH Publication No. 89-2247.

23. Kaste LM, Selwitz RH, Oldakowski RJ, Brunelle JA, Winn Dm, Brown LJ. Coronal caries in the primary and permanent dentition of children and adolescents 1-17 years of age: United States, 1988-1991. *J Dent Res* 1996; 75(Spec Iss):631-641.

24. Brown, JL, Wall TP, Lazar V. Trends in total caries experience: permanent and primary teeth. *J Am Dent Assoc* 2000; 131(2): 223-231.

25. National Center for Health Statistics, Centers for Disease Control and Prevention. *Health, United States, 2009.*

26. Shwartz M, Gröndahl HG, Pliskin JS, Boffa J. A longitudinal analysis from bite-wing radiographs of the rate of progression of approximal carious lesions through human dental enamel. *Arch Oral Biol* 1984; 29(7): 529-536.

27. Pitts N, Rimmer PA. An *in vivo* comparison of radiographic and directly assessed clinical caries status of posterior approximal surfaces in primary and permanent teeth. *Caries Res* 1992; 26(2): 146-152.

28. Foster LV. Three year *in vivo* investigation to determine the progression of approximal primary carious lesions extending into dentine. *Brit Dent J* 1998; 185(7): 353-357.

29. Arrow, P. Incidence and progression of approximal carious lesions among school children in Western Australia. *Aust Dent J* 2007; 52(3): 216-226.

30. Beltrán-Aguilar ED, Barker LK, Canto MT, Dye BA, Gooch BF, Griffin SO, Hyman J, Jaramillo F, Kingman A, Nowjack-Raymer R, Selwitz RH, Wu T. Surveillance for dental caries, dental sealants, tooth retention, edentulism, and enamel fluorosis - United States, 1988-1994 and 1999-2002. *MMWR Surveillance Summaries* 2005; 54(03): 1-44.

31. Dye BA. Areval O, Vargas CM. Trends in paediatric dental caries by poverty status in the United States, 1988 – 1994 and 1999 – 2004. *Int J Paediatric Dent* 2010; 20(2): 132-143.

32. Dye BA, Thornton-Evans G. Trends in oral health by poverty status as measured by Healthy People 2010 objectives. *Public Health Rep* 2010; 125(6): 817-830.

33. Bibby BG, Shern RJ. Methods of caries prediction; proceedings of a workshop conference. Washington, DC: IRL Press, Inc., 1978.

34. Holm AK. Dental health in a group of Swedish 8-year-olds followed since the age of 3. *Community Dent Oral Epidemiol* 1978; 6(2): 71-77.

35. Russell JI, MacFarlane TW, Aitchison TC, Stephen KW, Burchell CK. Prediction of caries increment in Scottish adolescents. *Community Dent Oral Epidemiol* 1991; 19(2): 74-77.

36. Menghini G, Steiner M, Thomet E, Rath C, Marthaler T, Imfeld T. Further caries decline in Swiss recruits from 1996 to 2006. *Schweiz Monatsschr Zahnmed* 2010; 120(7): 590-595.

37. Roberts-Thomson K, Stewart JF. Risk indicators of caries experience among young adults. *Aust Dent J* 2008; 53(2): 122-127.

38. Carlos JP, Wolfe MD. Dental caries: historic and current perspectives. *Compend Contin Educ Dent* 1988; Vol #9 (supplement 11): S356-S364.

39. Leiendecker TM, Martin GC, Moss DL, Mongeau SW, Chaffin JG, Dela Cruz GG. 2008 DOD Recruit Oral Health Survey. Tri-Service Center for Oral Health Studies, Uniformed Services University of the Health Sciences: 14.

40. Leiendecker TM, Martin G, Moss DL. 2008 DoD Recruit Oral Health Survey: A report on clinical findings and treatment needs. *Mil Med* 2011; 176(8; Supplement): 1-44.

41. U.S. Census Bureau. 2005-2009 American Community Survey. Oct 27, 2009.

42. Demographics 2009 Profile of the Military Community. Office of the Deputy Under Secretary of Defense. pp iii-iv.

43. Stahl JW, Katz RV. Occlusal dental caries incidence and implications for sealant programs in a US college student population. *J Public Health Dent* 1993; 53(4): 212-218.

44. Chief, Bureau of Medicine and Surgery. Oral disease risk management protocols in the Navy military health system. Washington, DC: Department of the Navy Bureau of Medicine and Surgery, BUMED Instruction 6600.16A, 23 August 2010.

45. Featherstone JD. Remineralization, the natural caries repair process- the need for new approaches. *Adv Dent Res* 2009; 21(1): 4-7.